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CHARACTERIZATION OF DIOXINS, FURANS AND PCBs IN RANDOM SOIL SAMPLES COLLECTED FROM THE ROCKY MOUNTAIN ARSENAL

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APPROVALS

This report has been prepared for and by the U.S. Environmental Protection Agency, Region 8. The results and conclusions presented in this report are accepted by EPA Region 8 as correct and appropriate.

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1.0 INTRODUCTION

Dioxins are a class of chemicals that are of potential human health concern because they may pose an increased risk of cancer and other adverse health effects at very low exposure levels. As a consequence, regulatory agencies often perform a thorough evaluation of potential risks from dioxins at sites of regulatory concern, especially sites involved in the manufacture of certain chlorinated pesticides and other chemicals. One site of this type is the Rocky Mountain Arsenal (RMA), located near Denver, Colorado.

However, the occurrence of dioxins in site soils is not always evidence of a site-specific release, since dioxins can be formed and released to the environment from multiple sources. Historically, the largest source has been atmospheric deposition resulting from incineration of medical and municipal organic wastes which have high contents of chlorine (EPA 1994a). In addition, dioxins can be formed in low levels from the combustion of many other types of organic precursors such as coal and wood, so dioxins can also be released from power plants, wood burning furnaces, forest fires, etc. (EPA 1998b).

Because of these multiple potential sources of dioxin release to the environment, it is often difficult to know whether dioxin levels observed in soil at a particular location are attributable to some specific local "point" source (e.g., pesticide or chemical manufacturing), or whether the levels represent typical "ambient" or ubiquitous concentrations due to other non-point sources. In order to make this judgement, accurate and reliable data are needed on dioxin levels in typical area soils. However, as discussed in USEPA (1999), available data on ambient levels of dioxins in soil are very limited and are of uncertain quality and relevance. Consequently, the USEPA Region VIII, working in cooperation with State and local governmental agencies, recently completed a study to characterize the typical ranges of dioxin levels in ambient soils in the Denver front range area (USEPA 2000c). These data provide an adequate basis for comparing dioxin levels at specific sites with those observed in the general area, in order to judge whether the site is contaminated with dioxins attributable to some site-specific source and release pathway.

This purpose of this study is to summarize data on the levels of dioxin in random soil samples collected from across the RMA, and to compare the site data with the regional ambient data in order to judge whether levels at the RMA are elevated compared to other comparable locations in and about the greater Denver area, and, if so, whether the levels are in a range of potential human health concern to on-site workers.

Other reports which are part of this project and which provide additional information on the absolute and relative level of dioxins in on-site and off-site soils include:

Evaluation of Potential Human Health Risk from Dioxins, Furans and PCBs in Soil at the Western Tier Parcel of the Rocky Mountain Arsenal (USEPA 2000a)

Characterization of Dioxins, Furans and PCBs in Soil Samples Collected From Historic Use Areas of the Rocky Mountain Arsenal (USEPA 2000b)

Characterization of Dioxins, Furans and PCBs In Soil Samples Collected from the Denver Front Range Area (USEPA 2000c)

2.0 METHODS

A detailed description of the rationale, methods, and Standard Operating Procedures (SOPs) used in this study are provided in the Project Plan for the study (USEPA 1999c). A summary of key elements of the study design and of the methods employed is presented below.

2.1 Calculation of TEQ

2,3,7,8-Tetrachlorodibenzodioxin (TCDD) is the most potent of a group of related chemicals that include other congeners of dioxins, furans, and polychlorinated biphenyls (PCBs). For the purposes of this report, the term "dioxins" is meant to refer to the set 17 dioxins and furans and the set of 12 PCBs that bind to the aryl hydrocarbon (Ah) receptor and possess toxic characteristics similar to those of TCDD. These so-called "Ah-agonists" are listed in **Table 1**.

Not all dioxin congeners are equally toxic. The relative toxicity of a congener, compared to that of TCDD is expressed in terms of the Toxicity Equivalency Factor (TEF). **Table 1** lists consensus TEF values for mammals (including humans), birds, and fish. These TEF values were developed by a panel of experts assembled by the World Health Organization (Van den Berg et al. 1998). Note that TEFs are often based on limited data, and so they are only approximations of the relative toxicity of each congener, rounded to the nearest half order of magnitude.

The aggregate toxicity of a mixture of different dioxins in an exposure medium (soil, food web items, etc.) is a complex function of a) concentrations of each congener in media, b) daily intake of the medium, c) absorption of each congener from that medium, and d) congener-specific TEF values. However, for purposes of screening-level evaluations of dioxin concentrations in soil samples, it is usually most convenient to calculate the concentration of TCDD-Equivalents (TEQ) present in the soil, as follows:

$$TEQ = \sum_{i=1}^{i=29} (C_i \times TEF_i)$$

This approach allows a comparison of different soils in terms of a single value (the TEQ for the sample) rather than having to compare up to 29 different values. For the purposes of this report, the TEQ values are based on the TEFs for mammals (humans).

2.2 Soil Sampling

Sampling Locations

The RMA is an area of approximately 27 square miles. As shown in **Figure 1**, this area is divided into 28 Sections. One grab sample was collected from each section at a randomly selected location. These sampling locations are indicated by red "x's" in Figure 1.

Sampling Depth

Because dioxins nearly always bind tightly to soil, it is expected that any dioxin contamination in soil that has occurred chiefly as result of atmospheric deposition and/or application of herbicides will be restricted to the surface. Thus, surface soil is the exposure medium of chief concern for both human and ecological receptors. Therefore, all soil samples collected for this study were grab samples collected at 0-2 inches in depth.

Sample Collection and Storage

Samples were collected using a stainless steel trowel. A ruler was used to ensure that the actual depth to which soil was collected was within ½ inch of the target (i.e., a bottom depth of no less than 1.5 inches and no greater than 2.5 inches). The soil was placed directly into a clean 16-oz amber glass jar with a teflon-lined lid, and these bottles were stored at room temperature in the dark.

2.3 Sample Preparation

All samples collected in the field were submitted under chain-of-custody to Columbia Analytical Services (CAS) for sample preparation. Each sample was air dried to constant weight, followed by coarse-sieving through a #10 (2 mm) stainless steel screen. The fraction passing the screen is referred to as the "bulk" fraction. Approximately 100 g of the bulk sample was placed in a clean amber glass jar and stored for future used. The remainder of the bulk sample was further sieved through a 60-mesh (250 um) sieve in order to isolate soil particles less than 250 um in diameter. This fraction (referred to as the "fine" fraction) was isolated because it is believed that fine soil particles are more likely to be ingested by hand to mouth contact that coarse particles, and hence it is concluded that this soil fraction is the most relevant for evaluating human health risk. All of the fine material passing the 250 um sieve was placed in a clean amber glass bottle for analysis and storage.

2.4 Sample Analysis

Following sample preparation as described above, samples were submitted under chain of custody to Midwest Research Institute (MRI) for chemical analysis. Analysis of dioxins in soil samples requires a sophisticated extraction and clean-up procedure. This procedure is detailed in USEPA (1999c) Standard

Operating Procedure 11. In brief, the congeners are determined using isotope dilution method via high resolution gas chromatography/mass spectrometry (HRGC/HRMS). Samples are fortified with ^{13}C-labeled PCDD/PCDF/PCB isomers and extracted with an organic solvent. Before cleanup of the extract, the analytes are exchanged into hexane and fortified with ^{37}Cl-labeled *2,3,7,8*-tetrachlorodibenzo-*p*-dioxin. Finally, the extract is sequentially partitioned against concentrated acid and base solutions.

The Method Detection Limit (MDL) for dioxins/furans by this analytical method is defined as a signal that is 2.5 times the average signal noise. An estimate of the average signal noise is available for each analyte in each samples, so the MDL varies from sample to sample and from analyte to analyte. The Method Quantitation Limit (MQL) is based on the lowest calibration standard used and is defined as a signal that is 10-times the average signal noise. Because the noise level varies from sample to sample and analyte to analyte, DLs and QLs also vary from sample to sample and from congener to congener. All congeners that yielded signals that were below the sample-specific detection limit for that congener (signal/noise ratio < 2.5) were evaluated by assuming a concentration value equal to ½ the detection limit for that congener.

2.5 Quality Assurance

A number of steps were taken to obtain data that would allow an assessment of the accuracy and reliability of the data collected. Key elements of the Quality Assurance program are summarized below.

Performance Evaluation Samples

Performance Evaluation (PE) samples are samples of soil that contain know quantities of analyte and that are submitted blind to the analytical laboratory. In this study, three different PE samples were used. These were obtained from EPA's Quality Assurance Technical Support (QATS) laboratory . Nominal values (ppt as TEQ in bulk soil, based on PCDD/PCDF congeners only) are listed below:

Description	**Nominal Value (ppt TEQ in bulk soil)**
Native western soil	< 2
Low standard	35
Medium standard	59

One aliquot of each these three QATS PE samples was submitted to the laboratory along with each set of 14 field samples. In some cases the sample was submitted un-sieved (bulk), and in other cases the samples was sieved, and only the fine fraction was analyzed.

Field Splits and Duplicates

A field duplicate is a second sample of soil collected at the same location as the first sample was collected, by alternating scoops of soil that was placed into the sample jar and into the duplicate jar. A sample split is a specimen that is generated by dividing a single field sample into two parts; in this case, a second aliquot from four total aliquots of sieved soil was submitted from the EPA archiving laboratory in Golden, CO, to the analytical laboratory. Both field duplicate and laboratory split samples were given unique and random identifying labels, so as to be blind to the laboratory analysts. Analysis of these types of samples provided data on the variability within and between related samples. One sample of each type was submitted to the laboratory with each set of about 14 field samples.

Laboratory Quality Control Samples

Laboratory QA samples are samples prepared and run by the laboratory in a non-blind fashion to monitor the performance of the analytical method. Laboratory QA samples included **Method Blanks** (analyte-free soil), **Laboratory Control Samples** (similar to PE samples, but the identity and true concentration are known to the laboratory), and **Method Duplicates** (investigative samples that are split prior to sample preparation at the analytical laboratory).

Data Validation/Verification

All data from MRI were subjected to a data verification check that was performed by RMA contractors (see SOP 12 in the Project Plan). No significant problems were detected in this verification check.

Following verification, all data values were reviewed by EPA to assign data usability flags. **Table 2** summarizes the data quality flags codes that were used, along with a description of the effect of the flag on the data usability assessment. In accord with USEPA (1992) data usability guidelines (Data Usability for Risk Assessment in Superfund), these flags are used for producing two data sets:

1) a semi-quantitative set of results with a value (actual or proxy as per above flags) for each congener; this result is referred to in this report as the "**Full**" TEQ value

2) a quantitative data set with more certain quantitative values (actual or proxy as per above flags) for only the congeners that have no disqualifying flags (D, JN, R and LT); this result is referred to in this report as the "**Quantitative**" TEQ value.

This distinction is made to help evaluate the effects of estimated values on TEQs and to evaluate profiles.

3.0 RESULTS

Detailed analytical results for each field sample are presented in **Appendix A1**, and detailed results for each QA sample run as part of this study are presented in **Appendix A2**. Graphical representations are presented in **Appendix B**. The results are summarized below.

3.1 TEQ Values

Table 3 presents the results (expressed as ppt of TEQ) for each of the 28 grab samples collected during the study. The spatial pattern for full TEQ values based on dioxins and furans only (excluding PCBs) are shown in **Figure 2**.

As seen, most samples (25 out of 28) had full TEQ values that were less than 3 ppt. TEQ values were slightly elevated (compared to the rest of the samples) in Section 1 (26 ppt), Section 2 (8 ppt), and Section 35 (5 ppt), all of which are located in the South Plants area of the RMA. As discussed in USEPA (2000b), other samples collected in this area support the conclusion that dioxin levels are slightly elevated compared to the rest of the RMA in the South Plants area, but that contaminant levels tend to fall off rapidly as a function of distance from this historic source area.

Comparison of the values for Full and Quantitative in Table 3 reveal that in most cases the two values are similar, especially for the samples with elevated levels, with an average difference of about 0.3 ppt. This indicates that congeners at or below the quantitation limit do not contribute strongly to the estimated total value.

3.2 Contribution of PCBs

As noted above, the TEQ values presented in the right-hand section of Table 3 are based on the sum of TEQ values across 17 dioxin/furan congeners and 12 dioxin-like PCBs. Comparison of the values for PCBs alone (center section of Table 3) to the values in the right hand section (summed across all congeners) reveals that PCBs contribute an average of about 30-35% to TEQ values, with the majority (65-70%) being attributable to PCDDs and PCDFs.

3.3 Contribution of Specific Congeners

The congener composition of a soil sample may provide useful information about the source of the material, and helps to reveal which specific congeners are contributing the majority of the TEQ levels.

The mean contribution of each congener to TEQ is summarized in **Table 4**. As seen, most of the TEQ (full and/or quantitative) is contributed by pentachloro- and hexachloro-dioxins and furans, with an additional contribution from 1,2,3,4,6,7,8-HpCDD and from PCB-126. TCDD itself contributes an average of less than 2% of the total.

3.4 Quality Assurance Samples

Quality assurance samples analyzed as part of this study indicate that the data are reliable and accurate.

Method Blanks

Two method blanks were included with the samples for this study. The values for full TEQ were both 0.2 ppt. This indicates that there is no significant source in dioxin or PCB contamination within the laboratory.

Splits and Duplicates

TEQ values for duplicate and split pairs are as follows:

Sample	Full	Quantitative
S-1 S-1 Split	25.4 7.0	24.6 6.8
S-5 S-5 Split	1.8 1.1	1.5 0.2
S-23 S-23 Dup	0.3 0.4	0.2 0.3
S-35 S-35 Split	3.6 3.1	3.2 2.7

As seen, except for the first pair (S-1), there is good agreement between splits and duplicate pairs, with an average difference of less than 2 ppt. The basis for the discrepancy between the original and split result for sample S-1 is not known, but is considered to be atypical and is currently being investigated.

Blind Performance Evaluation Samples

Analytical results for the soil standards (PE samples) obtained from QATS are summarized below.

Sample	Full TEQ (ppt) (PCDD/PCDF Only)			
	Bulk		Sieved	
	Nominal	Measured	Nominal	Measured
Clean Soil	< 2	NM	--	1.9 ± 1.2 (N=2)
Low Standard	35	NM	--	69 ± 2 (N=2)
Medium Standard	59	NM	--	121 ± 8 (N=2)

NM = Not measured

As seen, measured values for PE samples that were sieved before analysis are about twice as high as the nominal values for the bulk PE samples. This indicates that dioxins and furans tend to be more concentrated (on a mass per unit mass basis) in fine particles than in bulk soil, as would be expected for a material that adheres to the surface of particles, since the surface area to mass ratio increases as particle size decreases.

Laboratory Spikes

Analytical recovery of congeners from 2 different laboratory spikes (nominal full TEQ = 252 ppt) were 91% and 95%, respectively.

4.0 DISCUSSION

Comparison to Human-Health Based Guidelines

One of the reasons for performing this study was to determine whether dioxin levels in on-site soils might be of health concern to on-site workers. The concentration in soil that is identified by USEPA as the potential level of concern for workers is 5,000-20,000 ppt (EBASCO 1994). Inspection of Table 3 reveals that all of the samples collected in this study, including the samples from the South Plants area of the site (the region with the greatest impact from historic releases), the full TEQ for TCDDs and TCDFs are all far below the level of potential health concern to workers:

Health Criterion:	5000 ppt
Maximum RMA Grab sample	25 ppt
Mean RMA Grab sample	2 ppt

It should also be noted that the areas of RMA with the highest dioxin levels are currently undergoing soil remediation due to the presence of organo-chlorine pesticide (OCP) contamination. Once this remediation is complete, it is expected that dioxin levels on the RMA will be approximately the same as for any other open space area in the Denver front range area.

Comparison to Denver Front Range Area Background Levels

Figure 3 compares the distribution of concentration values observed at the random sampling locations within RMA with values observed at sampling locations around the greater Denver front range area (USEPA 2000c). As seen, the concentration values at RMA are similar to levels observed in open space and agricultural areas, and are lower than values observed in commercial, industrial and residential areas. Multiple pair-wise comparisons using the Mann-Whitney rank sum test indicate that there is no statistical difference between the on-post random samples and the Denver front range data sets for open space ($p = 0.966$) or agricultural lands ($p = 0.834$), while the on-post random samples are different (lower) than the off-post commercial, industrial and residential data sets ($p < 0.05$).

5.0 SUMMARY AND CONCLUSIONS

The concentration of dioxins is low in most samples of soil collected from the RMA, although small elevations are observable in some samples collected from areas close to the former chemical manufacturing operations (the South Plants area). The distribution of values across the site is not statistically different from values observed in open space and agricultural areas around the Denver front range area, and all of the on-site values are far below a level of health concern to on-site workers.

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Table 1. List of Analytes and TEFs

Class	Target Analyte	TEF		
		Mammals	Birds	Fish
Dibenzo-p-dioxins (PCDDs)	2,3,7,8-TCDD	1	1	1
	1,2,3,7,8-PeCDD	1	1	1
	1,2,3,4,7,8-HxCDD	0.1	0.05	0.5
	1,2,3,6,7,8-HxCDD	0.1	0.01	0.01
	1,2,3,7,8,9-HxCDD	0.1	0.1	0.01
	1,2,3,4,6,7,8-HpCDD	0.01	< 0.001	0.001
	OCDD	0.0001	0.0001	<0.0001
Dibenzofurans (PCDFs)	2,3,7,8-TCDF	0.1	1	0.05
	1,2,3,7,8-PeCDF	0.05	0.1	0.05
	2,3,4,7,8-PeCDF	0.5	1	0.5
	1,2,3,4,7,8-HxCDF	0.1	0.1	0.1
	1,2,3,6,7,8-HxCDF	0.1	0.1	0.1
	1,2,3,7,8,9-HxCDF	0.1	0.1	0.1
	2,3,4,6,7,8-HxCDF	0.1	0.1	0.1
	1,2,3,4,6,7,8-HpCDF	0.01	0.01	0.01
	1,2,3,4,7,8,9-HpCDF	0.01	0.01	0.01
	OCDF	0.0001	0.0001	<0.0001
PCBs	3,3',4,4'-TCB (77)	0.0001	0.1	0.0005
	3,4,4',5-TCB (81)	0.0001	0.05	0.0001
	3,3',4,4'-5-PeCB (126)	0.1	0.1	0.005
	3,3',4,4',5,5'-HxCB (169)	0.01	0.001	0.00005
	2,3,3',4,4'-PeCB (105)	0.0001	0.0001	< 0.000005
	2,3,4,4',5-PeCB (114)	0.0005	0.0001	< 0.000005
	2,3',4,4',5-PeCB (118)	0.0001	0.00001	< 0.000005
	2',3,4,4',5-PeCB (123)	0.0001	0.00001	< 0.000005
	2,3,3',4,4',5-HxB (156)	0.0005	0.0001	< 0.000005
	2,3,3',4,4',5'-HxCB (157)	0.0005	0.0001	< 0.000005
	2,3',4,4',5,5'-HxCB (167)	0.00001	0.00001	< 0.000005
	2,3,3',4,4',5,5'-HpCB (189)	0.0001	0.00001	< 0.000005

TEF = Toxicity Equivalency Factor
TEF values are consensus estimates recommended by WHO (Van den Berg et al. 1998)

Table 2. Definition, Application, and Uses of Data Flags

Validation Flags	Meaning of Flags for Dioxin Analyses in Soils and Tissues by the MRI Lab	* Usability of DataSets	
		Full data set used (*semi-quantitative*)	**Quantitative** (qualified sub-set used)
E	**E**stimated Maximum Potential Concentration; the relative ion abundance ratios did not meet the acceptance limits.	use value	use ½ value
D	EMPC is caused by polychlorinated **D**iphenyl ether interference.	use ½ value	don't use
B	Analyte was detected in associated Method **B**lank, sample concentration <5x MB concentration.	use value	use ½ value
C	Concentration is above upper **C**alibration Standard; result is an estimate, flagged C by lab and J added by validator.	use value	use value
I	Recovery of 13C-labeled **I**sotopic analyte outside of criteria	use value	use value
J	Estimated: e.g., isotopic standard is outside CCAL range, native analyte recovery in LCS is outside criteria, etc.	use value	use ½ value
NJ	Presumptive evidence for the presence of an analyte with an estimated value; if used for 2378-TCDF, see "U" below.	use ½ value	don't use
S	Peak is **S**aturated; result, if calculated, is flagged by the validator as an estimate - "J".	use value	use value
U	**U**nconfirmed: column is not specific for 2,3,7,8-TCDF; confirmation not requested. Validator now uses "NJ" flag.	use value	use ½ value
R	**R**ejected: result is invalid and not usable.	use ½ EDL	don't use
***use of MRI Laboratory's reported "LT" (less than) values* <MQL (10 x Signal:Noise)**			
LT *applied **first** to data, then apply flags!*	"LT" is not a true "flag", but if a LT result is a "**detect**" **above the MDL** (2.5 x Signal:Noise = lab EDL), then	use value	use ½ value
	"LT" is not a true "flag", but if a LT result is a "**non-detect**" **below the MDL** (2.5 x Signal:Noise = lab EDL), then	use ½ EDL	don't use

* Per concepts in the 1992 EPA Data Usability for Risk Assessment in Superfund guidance, the above flags are to be used for producing two data-sets: 1) a "**Full**" set of semi-quantitative results with an **actual or proxy value for each of the 29 measured congeners**; and 2) a "**Quantitative**" partial set of results with more certain identification and more accurate quantities of congeners which have **no disqualifying flags (D, JN, R or LT) or use limited proxies (E, B, J or U)**. This distinction is made to better understand and limit the artifactual impacts of the less certain estimated values on TEQs, analyzing this sensitivity by comparing TEQs from these two data-sets and evaluating congener profiles with only the analytes that are able to be quantitated.

Source: EPA R8 Soil and RMA Tissue Studies of Dioxins, 2000, ref. RMA/EAL SOP 803

Table 3. TEQ Values for RMA Random Grab Soil Samples

Section	Dioxins/Furans		PCBs		Total	
	Full	Quant	Full	Quant	Full	Quant
S1	25.40	24.63	0.82	0.48	26.22	25.11
S2	7.25	7.05	1.15	1.10	8.40	8.15
S3	0.66	0.60	0.35	0.33	1.01	0.93
S4	0.58	0.42	0.48	0.47	1.06	0.89
S5	1.82	1.50	0.22	0.20	2.04	1.70
S6	1.63	1.27	0.24	0.22	1.87	1.49
S7	0.97	0.91	0.41	0.40	1.38	1.31
S8	0.27	0.16	0.10	0.09	0.36	0.25
S9	1.57	1.36	1.24	1.23	2.81	2.58
S11	1.01	0.81	0.63	0.62	1.64	1.43
S12	0.71	0.36	0.35	0.33	1.06	0.69
S19	1.28	1.19	0.76	0.74	2.04	1.93
S20	0.68	0.36	0.20	0.19	0.88	0.55
S22	0.73	0.48	0.34	0.33	1.07	0.81
S23	0.35	0.23	0.11	0.06	0.46	0.29
S24	0.34	0.18	0.18	0.16	0.52	0.34
S25	0.14	0.02	0.04	0.01	0.18	0.02
S26	0.76	0.65	0.30	0.28	1.06	0.93
S27	0.21	0.18	0.22	0.21	0.43	0.39
S28	1.52	1.26	1.23	1.22	2.75	2.48
S29	0.30	0.21	0.14	0.13	0.43	0.33
S30	0.52	0.24	0.15	0.14	0.67	0.38
S31	1.95	1.65	0.39	0.37	2.34	2.03
S32	0.80	0.52	0.25	0.24	1.05	0.76
S33	0.83	0.57	0.79	0.78	1.62	1.35
S34	0.95	0.86	0.72	0.71	1.67	1.56
S35	3.59	3.16	1.51	0.83	5.09	3.99
S36	1.53	1.26	0.45	0.43	1.98	1.69

All TEQ values are expressed in units of ppt

Table 4. Relative Contribution of Congeners to Full TEQ

Analyte	Mean Percent Contribution to TEQ	
	Full	Quant
2,3,7,8-TCDF	1.4%	0.0%
2,3,7,8-TCDD	1.4%	0.6%
1,2,3,7,8-PeCDF	2.7%	2.8%
2,3,4,7,8-PeCDF	9.4%	7.8%
1,2,3,7,8-PeCDD	9.5%	4.4%
1,2,3,4,7,8-HxCDF	8.5%	9.3%
1,2,3,6,7,8-HxCDF	5.4%	5.0%
2,3,4,6,7,8-HxCDF	3.2%	2.9%
1,2,3,7,8,9-HxCDF	5.0%	4.3%
1,2,3,4,7,8-HxCDD	1.9%	1.4%
1,2,3,6,7,8-HxCDD	3.8%	3.7%
1,2,3,7,8,9-HxCDD	4.4%	4.9%
1,2,3,4,6,7,8-HpCDF	3.8%	4.6%
1,2,3,4,7,8,9-HpCDF	1.2%	1.3%
1,2,3,4,6,7,8-HpCDD	7.3%	11.1%
OCDF	0.3%	0.3%
OCDD	0.6%	0.9%
PCB-81	0.0%	0.0%
PCB-77	0.1%	0.1%
PCB-123	0.0%	0.0%
PCB-118	1.3%	1.1%
PCB-114	0.1%	0.1%
PCB-105	0.6%	0.7%
PCB-126	26.4%	30.8%
PCB-167	0.0%	0.0%
PCB-156	1.0%	1.2%
PCB-157	0.3%	0.3%
PCB-169	0.3%	0.3%
PCB-189	0.0%	0.0%
Dioxins/Furans only	69.8%	65.3%
PCBs only	30.2%	34.7%
All	100.0%	100.0%

Cells greater than 5% have been shaded to highlight the main contributors

Figure 3. Comparison of RMA Random Samples to Denver Front Range Soils